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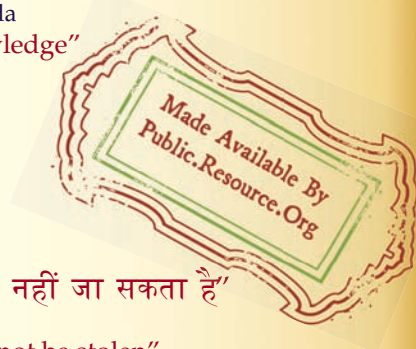
IS 11014-1 (1984): Piezoelectric Ceramic Materials, Part 1: General Aspects and Methods of Measurements [LITD 5: Semiconductor and Other Electronic Components and Devices]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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IS : 11014 (Part 1) - 1984

(Reaffirmed 2006)

Indian Standard

SPECIFICATION FOR
PIEZOELECTRIC CERAMIC MATERIALS

PART 1 GENERAL ASPECTS AND METHODS OF
MEASUREMENTS

UDC 621.372.412 [666.3/.7] : 620.1



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INDIAN STANDARDS INSTITUTION
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NEW DELHI 110002

*Indian Standard*SPECIFICATION FOR
PIEZOELECTRIC CERAMIC MATERIALSPART 1 GENERAL ASPECTS AND METHODS OF
MEASUREMENTSPiezoelectric Devices for Frequency Control and Selection
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*Indian Standard*SPECIFICATION FOR
PIEZOELECTRIC CERAMIC MATERIALS**PART 1 GENERAL ASPECTS AND METHODS OF
MEASUREMENTS****0. FOREWORD**

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 September 1984, after the draft finalized by the Piezoelectric Devices for Frequency Control and Selection Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The type designations of materials are based on the classification widely accepted by trade in many countries.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 1) covers with the general aspects and methods of measurements of the parameters of piezoelectric ceramic materials.

2. TERMINOLOGY

2.1 The following terms and definitions shall apply in addition to the terms and definitions given in IS : 1885 (Part 44)-1978†.

2.2 Piezoelectric Ceramic Element — Ceramic element which is fabricated and designed for specific transducer requirements with given geometric shape, size and orientation with respect to poling axis.

*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part 44 Piezoelectric devices.

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2.3 Dielectric Constant (K_3^T) — The ratio between the charge stored on an electroded slab of material brought to a given voltage and the charge stored on a set of identical electrodes separated by vacuum.

2.4 Dissipation Factor ($\tan \delta$) — The power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage to specified frequency.

2.5 Poling — A process of alignment of the dipoles of the domains of piezoelectric material by applying strong dc field.

2.6 Poling Axis — The axis along which the dc field is applied for poling.

2.7 Piezoelectric Charge Constant (d) — (a) Short circuit charge density developed per unit applied stress, and (b) Strain developed per unit applied field at constant stress.

2.8 Piezoelectric Voltage Constant (g) — (a) Open circuit field developed for a given applied stress, and (b) Strain developed for a given charge density at constant stress.

2.9 Resistivity — Resistance per unit length for unit cross section of the material.

2.10 Curie Temperature (Θ_c) — The temperature above which the dielectric constant of the ferroelectric material obey the Curie-Weiss Law and piezoelectricity of the material disappear.

3. TYPE DESIGNATION

3.1 The piezoelectric ceramic materials covered by this standard are type designated as follows:

<i>Materials</i>	<i>Type Designation</i>	<i>Remarks</i>
Barium titanate based (<i>BT</i>)	Type 1	Low signal
	Type 2	—
	Type 3	Low signal
Lead zirconim titanate based (<i>LT</i>)	Type 4	High signal
	Type 5	Low signal
	Type 6	Temperature compensated for filters
	Type 7	Temperature compensated for delay lines
	Type 8	Very high signal

3.1.1 Suitable modified suffixes may be used to indicate or denote any special property of the ceramic material.

For example, Type 5H — Modified 'lead zirconate titanate' material having high planar coupling coefficient and high dielectric constant.

3.2 The type designation of a particular piezoelectric ceramic material shall be specified in the relevant specification.

4. METHODS OF MEASUREMENTS

4.0 The methods of measurements of the following parameters of ceramic materials are covered:

<i>Parameters</i>	<i>Clause Ref</i>
a) Density (10^3 kg/m^3) (<i>d</i>)	4.2
b) Dielectric constant (K_g^T)	4.3
c) Dissipation factor ($\tan \delta$)	4.4
d) Resistivity (Ωcm) (<i>f</i>)	4.5
e) Planar coupling coefficient (K_p)	4.6
f) Piezoelectric charge constant $\times 10^{-12} \text{ C/N}$	4.7
g) Piezoelectric voltage constant $\times 10^{-3} \text{ Vm/N}$	4.8
h) Frequency constant (mHz)	4.9
j) Mechanical quality factor (Q_m)	4.10
k) Curie temperature (Θ_0)	4.11
m) Frequency of minimum and maximum impedance	4.12

4.1 General — For checking the properties/parameter of ceramic material it is necessary to making a test specimen of specified dimensions and shapes. Details of the test specimen shall be as specified in the relevant detail specification.

4.1.1 Classification of Tests — Type tests, acceptance tests and routine tests, number of samples for each group of tests shall be given relevant specification.

4.2 Density (*d*) — The dimensions of the ceramic disc shall be measured using vernier callipers, micrometer or any such device within an accuracy of 0.05 mm and the mass shall be measured to an accuracy of 1 mg. The density may then be calculated using the expression:

$$\text{Density} = \text{mass/volume}$$

4.3 Dielectric Constant — Dielectric constant shall be evaluated with the help of measured values of capacitance and dimensions in accordance with the following formula:

$$K_s^T = \frac{C t}{0.0885 A}$$

where

C = capacitance measured, pF;

A = area, cm²; and

t = thickness, cm.

The capacitance shall be measured at 1 kHz using standard 1 percent or better LCR bridge.

4.4 Dissipation Factor — The dissipation factor ($\tan \delta$) shall be measured using standard 1 percent or better LCR bridge at a frequency of 1 kHz.

4.5 Resistivity — This is derived from the following expression from the measured values of resistance, area and thickness:

$$\rho = R A/t$$

where

ρ = resistivity, Ω cm;

R = resistance, Ω ;

A = area, cm²; and

t = thickness, cm.

4.6 Planar Coupling Coefficient (K_p) — The value of planar coupling coefficient K_p may be evaluated from the graph (see Fig. 1) of K_p plotted against $\frac{f_n - f_m}{f_m}$, where f_n and f_m have been measured in accordance with 4.12.

4.7 Piezoelectric Charge Constant — The piezoelectric charge constant d_{33} may be calculated from the formula:

$$d_{33} = K_{33} \sqrt{8.85 \times 10^{-12} \times K_s^T S_{33}^E}$$

where

$$K_{33} = \frac{\text{Longitudinal coupling coefficient}}{\sqrt{\frac{\pi}{2} \frac{f_m}{f_n} \tan \frac{\pi}{2} \frac{f_n - f_m}{f_n}}}$$

In which f_n = frequency of maximum impedance,

f_m = frequency of minimum impedance,

K_s^T = dielectric constant, and

S_{33}^E = elastic compliance at constant electric field.

$$= \frac{S_{33}^D}{1 - K_{33}^2} \quad \frac{m/m}{N/m^2}$$

In which S_{33}^D = elastic compliance at constant charge density, and

K_{33}^2 = longitudinal coupling coefficient.

NOTE — A standard dynamic d_{33} tester may also be used for making this measurement.

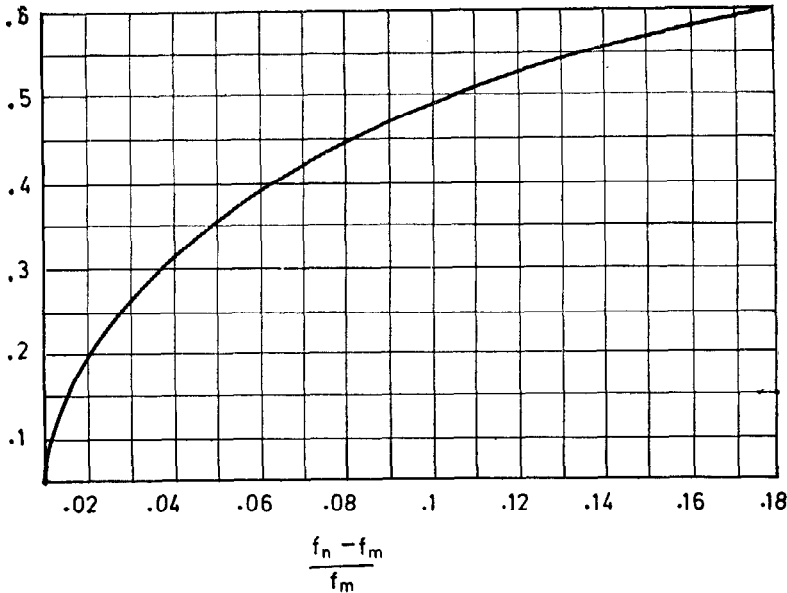


FIG. 1 GRAPH K_p vs $\frac{f_n - f_m}{f_m}$

4.8 Piezoelectric Voltage Constant — The piezoelectric voltage constant g_{33} may be calculated from the following formula:

$$g_{33} = \frac{d_{33}}{K_{33}^T \times 8.85 \times D \times 10^{-12}}$$

where

g_{33} = piezoelectric voltage constant,
 d_{33} = piezoelectric charge constant,
 K_{33}^T = dielectric constant, and
 D = diameter of disc.

4.9 Frequency Constant — This is derived from the product of frequency of resonance in thickness mode frequency of maximum impedance (f_n) and thickness in meter-hertz.

4.10 Mechanical Quality Factor — The mechanical quality factor Q_m may be calculated from the frequency of minimum impedance (f_m) the frequency of maximum impedance (f_n), the magnitude of the minimum impedance (Z_m) and capacitance (C).

$$Q_m = \frac{f_n^2}{2 \times f_m Z_m C (f_n^2 - f_m^2)}$$

4.11 Curie Temperature — The dielectric constant K_3^T is measured at different temperatures up to 400°C. The plot of K_3^T against temperature shows a peak and the corresponding temperature is the Curie temperature.

4.12 Frequency of Minimum and Maximum Impedance — The frequencies of minimum and maximum impedance are determined using resonance principle. A typical circuit diagram is given in Fig. 2. The various component values shall be selected based on the ceramic material parameter values.

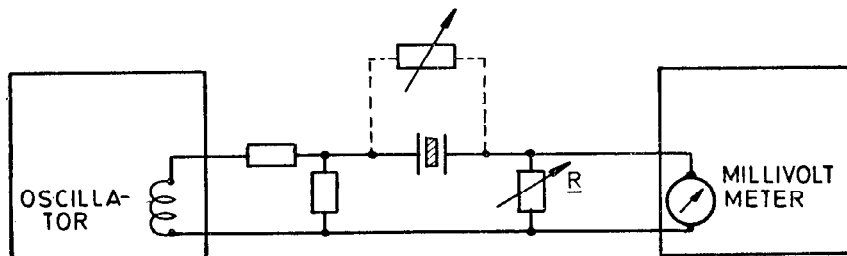


FIG. 2 TYPICAL CIRCUIT DIAGRAM

The frequency of the minimum impedance is determined by adjusting the oscillator to the frequency of minimum impedance at which, the meter shows a peak value. Read the frequency at the counter and record it as f_m . At the frequency of minimum impedance, substitute a calibrated variable resistance in place of specimen, and the resistance is adjusted for the same meter indication. This value of resistance is minimum impedance Z_m .

The oscillator is further adjusted for minimum reading on meter. Read the frequency at the counter and record it as f_n .

In determining the frequency of maximum impedance, stray capacitance across the test specimen causes the maximum impedance to occur at a frequency which is too low. Due to the high dielectric constants of most piezoelectric ceramics, this error is negligible when the specimen is thin and extended electrode area. However, when the specimen is an end-electroded rod a serious error or may be introduced by stray capacitance. To avoid this error, a special shielded holder is used.

5. MARKING

5.1 The following information shall be marked legibly and indelibly upon the piezoelectric ceramic materials:

- a) Type of material, and
- b) Direction of poling — a sign of plus (+) on the electroded surface which has positive potential during poling.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

<i>Quantity</i>	<i>Unit</i>	<i>Symbol</i>
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mole

Supplementary Units

<i>Quantity</i>	<i>Unit</i>	<i>Symbol</i>
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

<i>Quantity</i>	<i>Unit</i>	<i>Symbol</i>	<i>Definition</i>
Force	newton	N	1 N = 1 kg.m/s ²
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m ²
Frequency	hertz	Hz	1 Hz = 1 c/s (s ⁻¹)
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m ²